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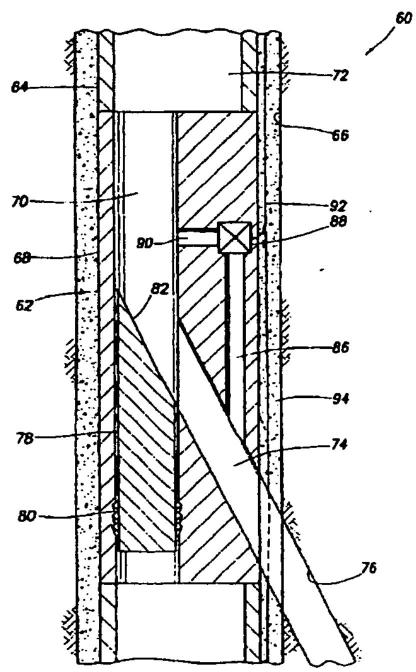
(54) Abstract Title: **Surface controlled subsurface lateral branch safety valve**

(57) A surface controlled subsurface lateral branch safety valve (88) provides flow controlled for each branch wellbore in a multilateral well. In a described embodiment, a completion system for a well having in intersection between parent (66) and branch wellbores (76) includes an apparatus having multiple passages formed therethrough. One passage (70) provides fluid communication between opposite ends of the apparatus in the parent wellbore, and another passage (74) provides guidance for drilling the branch wellbore. The apparatus further includes a flow control device (88), such as a surface controlled subsurface safety valve, which selectively controls fluid communication with the branch wellbore.



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This international application has entered the national phase early

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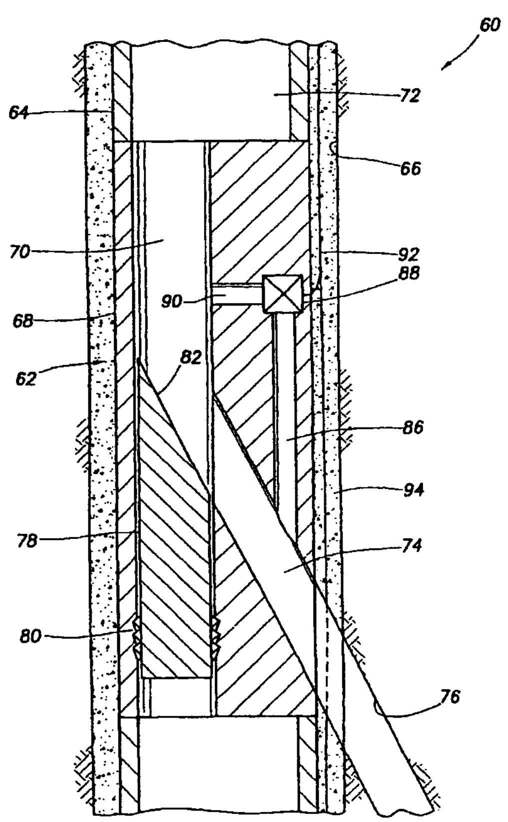
(54) Title: SURFACE CONTROLLED SUBSURFACE LATERAL BRANCH SAFETY VALVE



(57) Abstract: A surface controlled subsurface lateral branch safety valve (88) provides flow controlled for each branch wellbore in a multilateral well. In a described embodiment, a completion system for a well having in intersection between parent (66) and branch wellbores (76) includes an apparatus having multiple passages formed therethrough. One passage (70) provides fluid communication between opposite ends of the apparatus in the parent wellbore, and another passage (74) provides guidance for drilling the branch wellbore. The apparatus further includes a flow control device (88), such as a surface controlled subsurface safety valve, which selectively controls fluid communication with the branch wellbore.

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SURFACE CONTROLLED SUBSURFACE LATERAL BRANCH SAFETY VALVE

TECHNICAL FIELD

The present invention relates generally to operations performed and equipment utilized in conjunction with a subterranean well and, in an embodiment described herein, more particularly provides a surface controlled subsurface lateral branch safety valve and associated systems and methods.

BACKGROUND

In some jurisdictions, commingling production from different reservoirs is allowed. This is flow from each of multiple branch wellbores into a common main or parent wellbore extending to the surface. It is appreciated by those skilled in the art that this is a difficult task, and yet several systems have been proposed for complying with this requirement. Unfortunately, each of these proposed systems suffers from at least one major drawback.

SUMMARY

In carrying out the principles of the present invention, in accordance with an embodiment thereof, a well completion system is provided which solves the above problems in the art. In this embodiment, a surface controlled subsurface safety valve is used to control flow from each lateral branch wellbore in a multilateral well.

In one aspect of the invention, a completion system for a well having an intersection between first and second wellbores is provided. The system includes an apparatus having first and second passages formed therethrough. The first passage provides fluid communication between opposite ends of the apparatus in the first wellbore. The second passage provides guidance for drilling the second wellbore extending laterally from the first wellbore. The apparatus further includes a flow control device selectively controlling fluid communication with the second passage.

In another aspect of the invention, a method of completing a well having an intersection between first and second wellbores is provided. The method includes the steps of: interconnecting a mandrel as part of a casing string, a first longitudinal passage of the casing string extending through the mandrel; positioning the mandrel in the well at the desired intersection of the first and second wellbores; drilling the second wellbore by deflecting a cutting tool from the first passage and through a second passage formed in the mandrel; and flowing fluid between the first and second wellbores through the mandrel, without flowing fluid directly between the first and second passages.

In yet another aspect of the invention, an apparatus for use in completing a well having intersecting first and second wellbores is provided. The apparatus includes an elongated mandrel configured for interconnection in a casing string in the well. The mandrel has intersecting first and second passages formed therethrough. The first passage extends longitudinally through the mandrel, and

DETAILED DESCRIPTION

Illustrated in FIG. 1 is a prior art well completion system 10. In this system 10, multiple lateral or branch wellbores 12, 14, 16 are drilled extending outward from a main or parent wellbore 18. A completion string 20 is installed in a casing string 22 lining the parent wellbore 18.

The completion string 20 includes valves, such as sliding sleeve valves 24, 26, 28, for controlling flow between the respective branch wellbores 12, 14, 16 and the interior of the completion string. Packers 30, 32, 34, 36 provide isolation between the branch wellbores 12, 14, 16 and the respective valves 24, 26, 28 in the completion string. This arrangement permits flow from each branch wellbore 12, 14, 16 to be individually controlled by its respective valve 24, 26, 28.

However, the completion string 20 prevents access to the branch wellbores 12, 14, 16. The entire completion string 20 must be pulled from the well in order to provide access to any one of the branch wellbores 12, 14, 16. The completion string 20 must then be reinstalled in the well in order for production to resume.

Illustrated in FIG. 2 is another prior art well completion system 40. In this system 40, valves 42, 44, 46 are separately installed attached to respective packers 48, 50, 52 set in the branch wellbores 12, 14, 16. Thus, the valve 42 controls flow between the branch wellbore 12 and the parent wellbore 18, the valve 44 controls flow between the branch wellbore 14 and the parent wellbore, and the valve 46 controls flow between the branch wellbore 16 and the parent wellbore.

The valves 42, 44, 46 are individually operated via respective lines 54, 56, 58. The lines extend from the valves 42, 44, 46, through the packers 48, 50, 52 and into the parent wellbore 18. It will be readily appreciated that installation of the valves 42, 44, 46 and the corresponding lines 54, 56, 58 is very difficult and time-consuming, in particular requiring separate trips to install each of the valves and set its associated packer 48, 50, 52, and requiring running and interconnecting the various lines.

clearly understood that the mandrel may be made up of any number of separate elements in keeping with the principles of the invention.

Preferably, the mandrel 68 and the remainder of the casing string 64 are cemented within the parent wellbore 66 to secure the casing string in the parent wellbore and prevent fluid migration between zones or formations intersected by the parent wellbore and any branch wellbore intersecting the parent wellbore. Prior to cementing the casing string 68 in the wellbore 66, the passage 74 is rotationally oriented to face in a desired direction for drilling a branch wellbore 76. As used herein, the terms “cementing”, “cement” and the like are used to indicate any process using a material which is flowed between a tubular string and a wellbore, and which secures the tubular string in the wellbore and prevents fluid flow therebetween. Cement may include cementitious material, epoxies, other polymer materials, any hardenable and/or adhesive sealing material, etc.

After cementing, a deflecting device 78, such as a drilling whipstock, is installed in the passage 70. The device 78 engages a profile 80 formed internally in the mandrel 68. This engagement between the device 78 and the profile 80 rotationally aligns an upper deflecting surface 82 of the device with the passage 74.

One or more cutting tools, such as drills, mills, reamers, etc., are conveyed through the casing string 64 into the passage 70 and deflected laterally off of the surface 82 through the passage 74 to drill the branch wellbore 76. The apparatus 62 thus provides a convenient means for drilling the branch wellbore 76 extending outwardly from the parent wellbore 66. If multiple branch wellbores are desired, such as the branch wellbores 12, 14, 16 described above, multiple ones of the apparatus 62 may be interconnected in the casing string 64. The device 78 may then be installed in successive ones of the apparatuses 62 to drill the respective branch wellbores.

The device 78 may remain in the apparatus 62 while liners, well screens, or other equipment is installed in the branch wellbore 76. Alternatively, the device 78 could be replaced with another device better suited for deflecting such completion equipment into the branch wellbore 76. Note that the branch

As depicted in FIG. 3, lines 92 are shown connected to the flow control device 88. These lines 92 may be hydraulic, electric, fiber optic, or any other type of lines which may be used to operate and/or communicate with the flow control device 88 from a remote location, such as the earth's surface, or another location in the well.

Note that the lines 92 preferably extend in the parent wellbore 66 external to the casing string 64. Thus, the lines 92 do not obstruct the interior of the casing string 64 and are not subject to damage due to operations performed in, or equipment conveyed through, the casing string. A suitable system for running the lines 92 external to the casing string 64 is the "Flat Pack" available from Halliburton Energy Services, Inc.

The lines 92 may include a fiber optic line for sensing temperature distribution in the annulus 94 between the casing string 64 and the parent wellbore 66. Such a distributed temperature sensing system used internal to a casing string is described in U.S. Patent No. 5,163,321, the entire disclosure of which is incorporated herein by this reference. Of course, fiber optic lines may also be used to sense pressure in the annulus 94, as well.

The flow control device 88 may alternatively, or in addition, be communicated with or controlled remotely by means of telemetry. For example, electromagnetic, acoustic or pressure pulse telemetry may be used to transmit commands, codes or instructions from a remote location to a control module of the flow control device 88 to cause an actuator of the flow control device to open or close the device, or otherwise regulate flow therethrough. Such telemetry systems may also be used to transmit information from the flow control device 88 to the remote location, for example, to transmit indications of flow rate through the device, pressure drop across the device, temperature of fluid in the device, position of a closure member of the device, etc.

The flow control device 88 may use a downhole power supply. For example, the apparatus 62 may include batteries to supply power to the device 88. Recharging or replacement of the batteries is made much more convenient in the system 60, since the apparatus 62 is positioned in the parent wellbore 66,

4A & B to indicate elements similar to those previously described. In addition, the system 100 is depicted apart from the parent wellbore 66 for clarity of illustration and description.

Instead of the apparatus 62 of the system 60, the system 100 is shown in FIGS. 4A & B as including a more detailed and somewhat differently configured apparatus 102. However, the apparatus 102 still performs essentially the same functions as the apparatus 62 described above. For example, the passages 70, 74 are provided for flow longitudinally through the casing string and for flow between the interior of the casing string 64 and the branch wellbore 76, respectively. The passages 86, 90 are provided for flow control between the passages 70, 74 when the plug 84 blocks direct flow between the passages 70, 74. A flow control device 104 is provided for controlling the flow through the passages 86, 90.

As depicted in FIGS. 4A& B, the flow control device 104 is a valve of the type known to those skilled in the art as a sliding sleeve valve. The device 104 includes a tubular sleeve or closure member 106 which is reciprocably and sealingly received in the passage 86. By displacing the sleeve 106 in the passage 86, flow may be permitted or prevented between the passages 86, 90 as desired.

The sleeve 106 may be displaced by any means, such as a hydraulic actuator, electric actuator, optical actuator, etc. An actuator for the flow control device 104 has not been illustrated in FIGS. 4A & B for clarity, but such actuators are well known to those skilled in the art. Any type of actuator may be used in the flow control device 104 without departing from the principles of the invention.

Although a sliding sleeve valve is depicted as the flow control device 104 of the apparatus 102, it should be clearly understood that any type of flow control device may be used in the apparatus. For example, the device 104 could be a ball valve, a choke, or a safety valve, etc. The sleeve 106 could be another type of closure member, such as a ball or a flapper, etc. The flow control device 104 could be remotely controlled and operated, or the flow control device could operate automatically in response to conditions sensed downhole, as described more fully below.

a blowout, severing of the lines 92, fire, etc. By positioning one of the apparatus 102 in the casing string 64 at each of multiple branch wellbores in the well, flow from or into each of the branch wellbores can be individually controlled, thereby enhancing the safety of operations at the well.

FIG. 4B depicts a portion of the apparatus 102 showing the flow control device 104 in an open configuration. Flow is now permitted between the passages 86, 90 and, thus, between the passages 70, 74, as indicated by the arrows 122. Although the sleeve 106 is shown in a position in which the flow 122 is completely unobstructed, it will be readily appreciated that the sleeve could be positioned so that it partially obstructs the fluid flow, thereby restricting, but not completely preventing flow through the flow control device 104. The flow control device 104, therefore, may act as a choke to regulate the flow 122 therethrough.

The apparatus 102 further includes sensors 124, 126, 128, depicted in FIGS. 4A & B as being attached to a mandrel 130 of the apparatus. The sensors 124, 126, 128 may be any type or combination of sensors, for example, sensors which detect pressure, temperature, fluid identity, fluid composition, resistance, flow rate, viscosity, density and/or nuclear resonance, etc. The sensors 124, 126, 128 may include thermocouples, strain gauges, optical fibers, quartz pressure sensors, piezoelectric pressure sensors, neural networks, vibrating tubes, acoustic properties detectors, electromagnetic sensors, etc.

Representatively, in the system 100, the sensors 124, 126, 128 each includes pressure and temperature sensors. The sensor 124 senses pressure and temperature of fluid in the passage 70. The sensor 126 senses pressure and temperature of fluid in the passage 86. The sensor 128 senses pressure and temperature of fluid in the annulus 94 external to the mandrel 130.

With the flow control device 104 closed as depicted in FIG. 4A, the sensor 126 is still able to sense the pressure and temperature of fluid in the passage 74 through the sleeve 106, since the sleeve is tubular. Thus, the sensor 126 may be useful in sensing the shut-in pressure and temperature of the branch wellbore 76. This information may be useful in testing the branch wellbore 76, for example, to determine the appropriate method of completing the branch wellbore, to

reservoirs is commingled in the parent wellbore 66. If one of the apparatuses 102 is installed at each branch wellbore intersecting the different reservoirs, then the pressures in each of the reservoirs may be continuously monitored, along with the production rate from each reservoir, etc. This would allow the flow control devices 104 to automatically shut-in branch wellbores whose reservoir pressure is incompatible with the flowing pressure in the parent wellbore 66 (e.g., to prevent one reservoir from flowing into another reservoir), increase production from other branch wellbores, etc., without intervention into the well.

As another example, a sensor at a remote location, such as the earth's surface, may sense an emergency situation, such as a fire, and cause the flow control device 104 to automatically close. A sensed emergency situation may cause each of the flow control devices 104 of multiple apparatuses 102 interconnected in the casing string 64 to close, thereby shutting off fluid flow from multiple branch wellbores at the same time.9 As yet another example, the flow control device 104 may automatically close if the sensor 128 or a distributed temperature sensing system in the lines 92 detects a leak in the annulus 94 outside the casing string 64. Therefore, it will be readily appreciated that the system 100 provides a far greater degree of control and safety in operation of the well than has been available in the past.

As depicted in FIG. 4A, the casing string 64 above the apparatus 102 includes a seal bore or PBR 132. A lower end of a production tubing string 134 is sealingly received in the seal bore 132. Fluid produced from the branch wellbore 76 is flowed to a remote location via the production tubing string 134. This is a completion of the type known to those skilled in the art as a "monobore" completion, although any other type of completion in the parent wellbore may be used in keeping with the principles of the invention.

The mandrel 130 includes an internal orienting profile 136 formed in the passage 70 above the passage 90. This profile 136 may be used to anchor and/or orient various items of equipment in the mandrel 130. In an embodiment described below, the profile 136 is used in maintaining the flow control device 104.

The flow control device 144 and/or its batteries, seals, closure member, etc. may now be retrieved from the mandrel 142 by the kickover tool 152 and conveyed out of the well for recharging, repair or replacement. It may now be fully appreciated how the system 140 provides for convenient maintenance of the flow control device 144 which controls flow between branch and parent wellbores. This manner of maintaining the flow control device 144 may also be used in the systems 60, 100 described above, with appropriate modification.

Referring additionally now to FIG. 7, another system 160 incorporating principles of the invention is representatively and schematically illustrated. The system 160 is shown apart from the remainder of the well for illustrative clarity. The system 160 includes an apparatus 162 which is similar in many respects to the system 60 illustrated in FIG. 3. The same reference numbers are used to indicate elements shown in FIG. 7 which are similar to elements shown in FIG. 3.

The apparatus 162 includes a mandrel 164 which has the passages 70, 74 formed therein. One difference between the mandrel 164 depicted in FIG. 7 and the mandrel 68 depicted in FIG. 3 is that the mandrel 164 does not have a flow control device 166 positioned therein. Instead, the flow control device 166 is positioned external to the mandrel 164.

As shown in FIG. 7, the flow control device 166 is positioned above the mandrel 164. However, it should be understood that the flow control device 166 could be otherwise positioned relative to the mandrel 164. For example, the flow control device 166 could be below or laterally adjacent the mandrel 164, and the flow control device could be below or laterally adjacent the passage 74. Thus, any positioning of the flow control device 166 relative to the mandrel 164 may be used in keeping with the principles of the invention.

The passage 86 providing fluid communication between the passage 74 and the flow control device 166 extends external to the mandrel 164, where it connects to the flow control device. In a similar manner, the passage 90 providing fluid communication between the flow control device 166 and the passage 70 extends external to the mandrel 164. In fact, the passage 90 does not extend in the mandrel 164 at all, but instead extends through a sidewall of the

invention are achieved in the embodiments described herein, without undue complication or difficulty in installing and maintaining a well completion, without unduly restricting access to branch wellbores, and without requiring flow control devices to be installed in each of the branch wellbores.

However, it should be understood that flow control devices could be installed in branch wellbores and access to branch wellbores could be restricted without departing from the principles of the invention.

It may now be appreciated that the systems 60, 100, 160 described above are intelligent well completions, and the respective apparatuses 62, 102, 162 are portions of those intelligent well completions. As used herein, the term "intelligent well completion" is used to indicate a well completion that, without intervention, allows continuous downhole monitoring and/or continuous downhole control of wellbore fluids, and is deployed within a production and/or injection system. The sensors described herein, such as the sensors 124, 126, 128, provide the continuous downhole monitoring of wellbore fluids, and the flow control devices 88, 104, 166 provide the continuous downhole control of wellbore fluids.

Referring additionally now to FIG. 8, another system 170 is representatively illustrated. The system 170 includes a generally tubular wear bushing 172 which is installed in the passage 74 during drilling operations. The wear bushing 172 may be used in any of the systems and methods 60, 100, 160 described above. For example, in the system 100, the wear bushing 172 would be installed in the passage 74 while the branch wellbore 76 is being drilled. For clarity of description, the use of the wear bushing 172 will be described below as it is used with the system 100 shown in FIGS. 4A & B.

The wear bushing 172 preferably performs several functions. First, it lines the passage 74 to prevent wear due to the cutting tools, drill strings, etc. passing through the passage. Second, it protects an internal profile 174 formed in the passage 74. Third, it protects an internal seal bore 176 formed in the passage 74. Fourth, it isolates the passage 86 from the passage 74 (by means of seals 178 on the wear bushing 172 straddling the passage 86).

WHAT IS CLAIMED IS:

1. A completion system for a well having an intersection between first and second wellbores, the system comprising:

an apparatus having first and second passages formed therethrough, the first passage providing fluid communication between opposite ends of the apparatus in the first wellbore, and the second passage providing guidance for drilling the second wellbore extending laterally from the first wellbore, the apparatus further including a flow control device selectively controlling fluid communication with the second passage.

2. The system according to claim 1, wherein direct fluid communication between the first and second passages is prevented while the flow control device permits flow between the first and second passages via a third passage extending between the first and second passages.

3. The system according to claim 1, wherein direct fluid communication between the first and second passages is prevented while the flow control device permits flow between the second passage and a third passage extending to a remote location.

4. The system according to claim 1, wherein the apparatus further includes a plug preventing direct fluid communication between the first and second passages.

5. The system according to claim 4, wherein the plug is installed in the second passage, and the flow control device remains in direct fluid communication with the second passage while the plug is installed.

13. The system according to claim 10, wherein the wear bushing protects a seal bore formed in the second passage.

14. The system according to claim 10, wherein the wear bushing protects an internal profile formed in the second passage.

15. The system according to claim 10, wherein the wear bushing isolates the second passage from a third passage formed in the apparatus.

16. The system according to claim 1, wherein the apparatus includes a sensor which senses fluid properties external to the apparatus.

17. The system according to claim 1, wherein the flow control device is automatically operated in response to indications of fluid properties sensed by at least one sensor of the apparatus.

18. The system according to claim 17, wherein there are multiple ones of the apparatus, and wherein the flow control device of each of the apparatuses is used to control commingling of production from multiple reservoirs associated with the apparatuses.

received from at least one sensor sensing a fluid property in at least one of the first and second wellbores.

25. The method according to claim 20, further comprising the step of controlling operation of the flow control device from a remote location.

26. The method according to claim 25, wherein the controlling step further comprises controlling the flow control device operation via at least one line connected to the flow control device and extending to the remote location.

27. The method according to claim 26, wherein in the controlling step, the line is a hydraulic line.

28. The method according to claim 26, wherein in the controlling step, the line is an electric line.

29. The method according to claim 26, wherein in the controlling step, the line is a fiber optic line.

30. The method according to claim 25, wherein the controlling step further comprises controlling the flow control device operation via telemetry.

31. The method according to claim 30, wherein in the controlling step, the telemetry is electromagnetic telemetry.

32. The method according to claim 30, wherein in the controlling step, the telemetry is acoustic telemetry.

40. The method according to claim 19, wherein the drilling step further comprises installing a deflector in the mandrel, the mandrel deflecting the cutting tool from the first passage to the second passage.

41. The method according to claim 40, wherein the deflector installing step further comprises engaging the deflector with a profile formed in the mandrel.

42. The method according to claim 41, wherein the deflector engaging step further comprises rotationally aligning a deflection surface of the deflector with the second passage.

43. The method according to claim 19, further comprising the step of installing a liner string in the second wellbore through the second passage.

44. The method according to claim 19, further comprising the step of providing a sensor sensing a fluid property in the first passage.

45. The method according to claim 44, further comprising the step of transmitting an indication of the fluid property from the sensor to a remote location.

46. The method according to claim 45, wherein the transmitting step further comprises transmitting the indication to a remote location via at least one line connected to the sensor.

47. The method according to claim 45, wherein the transmitting step further comprises transmitting the indication via telemetry.

56. The method according to claim 54, wherein in the transmitting step, the telemetry is acoustic telemetry.

57. The method according to claim 54, wherein in the transmitting step, the telemetry is pressure pulse telemetry.

58. The method according to claim 51, wherein a flow control device is interconnected between the first and second passages, and wherein the sensor senses the fluid property in the second passage when the flow control device is closed.

59. The method according to claim 51, wherein a flow control device is interconnected between the first and second passages, and wherein the sensor senses the fluid property in the second passage when the flow control device is open.

60. The method according to claim 51, wherein a flow control device is interconnected between the first and second passages, and wherein the sensor senses the fluid property in the second passage through a closure member of the flow control device.

61. The method according to claim 19, further comprising the step of providing a sensor sensing a fluid property external to the mandrel.

62. The method according to claim 61, further comprising the step of transmitting an indication of the fluid property from the sensor to a remote location.

71. An apparatus for use in completing a well having intersecting first and second wellbores, the apparatus comprising:

an elongated mandrel configured for interconnection in a casing string in the well, the mandrel having intersecting first and second passages formed therethrough, the first passage extending longitudinally through the mandrel, and the second passage extending laterally relative to the first passage; and

a flow control device selectively permitting and preventing fluid communication with the second passage.

72. The apparatus according to claim 71, wherein the flow control device is positioned internal to the mandrel.

73. The apparatus according to claim 71, wherein the flow control device is positioned external to the mandrel.

74. The apparatus according to claim 71, wherein the flow control device selectively permits and prevents flow between the first and second passages.

75. The apparatus according to claim 74, further comprising a plug blocking flow directly between the first and second passages, the flow control device selectively permitting and preventing flow between the first and second passages via a third passage extending between the first and second passages.

76. The apparatus according to claim 71, wherein the flow control device selectively permits and prevents flow between the second passage and a third passage extending to a remote location.

86. The apparatus according to claim 83, wherein the line is a fiber optic line.

87. The apparatus according to claim 82, wherein the flow control device is operated via telemetry from the remote location.

88. The apparatus according to claim 87, wherein the telemetry is electromagnetic telemetry.

89. The apparatus according to claim 87, wherein the telemetry is acoustic telemetry.

90. The apparatus according to claim 87, wherein the telemetry is pressure pulse telemetry.

91. The apparatus according to claim 71, further comprising a tool installed in the mandrel and operative to retrieve a portion of the flow control device from within the mandrel.

92. The apparatus according to claim 91, wherein the flow control device portion is a closure member.

93. The apparatus according to claim 91, wherein the tool is engaged with a profile formed in the mandrel.

102. The apparatus according to claim 101, wherein the telemetry is electromagnetic telemetry.

103. The apparatus according to claim 101, wherein the telemetry is acoustic telemetry.

104. The apparatus according to claim 101, wherein the telemetry is pressure pulse telemetry.

105. The apparatus according to claim 71, further comprising a sensor sensing a fluid property external to the mandrel.

106. The apparatus according to claim 105, wherein the sensor senses the fluid property in the first wellbore.

107. The apparatus according to claim 105, wherein indications of the fluid property are transmitted from the sensor to a remote location.

108. The apparatus according to claim 107, wherein the fluid property indications are transmitted via at least one line connected to the first and second sensors.

109. The apparatus according to claim 108, wherein the line is an electric line.

110. The apparatus according to claim 108, wherein the line is a hydraulic line.

119. The apparatus according to claim 71, wherein the apparatus includes multiple ones of the mandrel, the mandrels being interconnected to each other so that the first passages of the mandrels are in fluid communication with each other.

120. The apparatus according to claim 71, wherein the apparatus includes multiple ones of the mandrel, the mandrel first passages forming portions of a casing string flow passage, and the flow control devices selectively permitting and preventing flow between the respective second passages and the casing string flow passage.

121. The apparatus according to claim 71, wherein the apparatus includes multiple ones of the mandrel, the mandrel first passages forming portions of a casing string flow passage, and at least one of the flow control devices selectively permitting and preventing flow between the respective second passage and a third passage extending to a remote location.

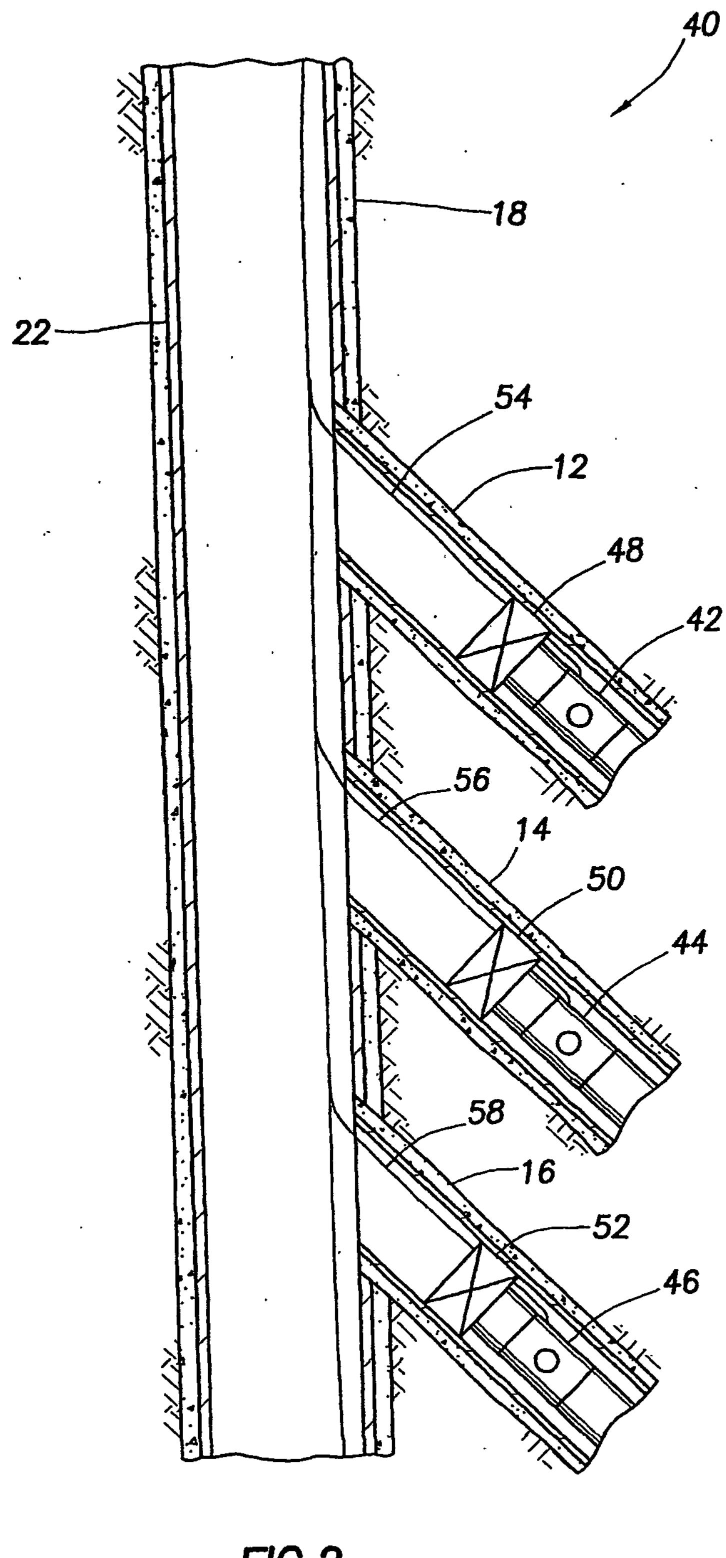
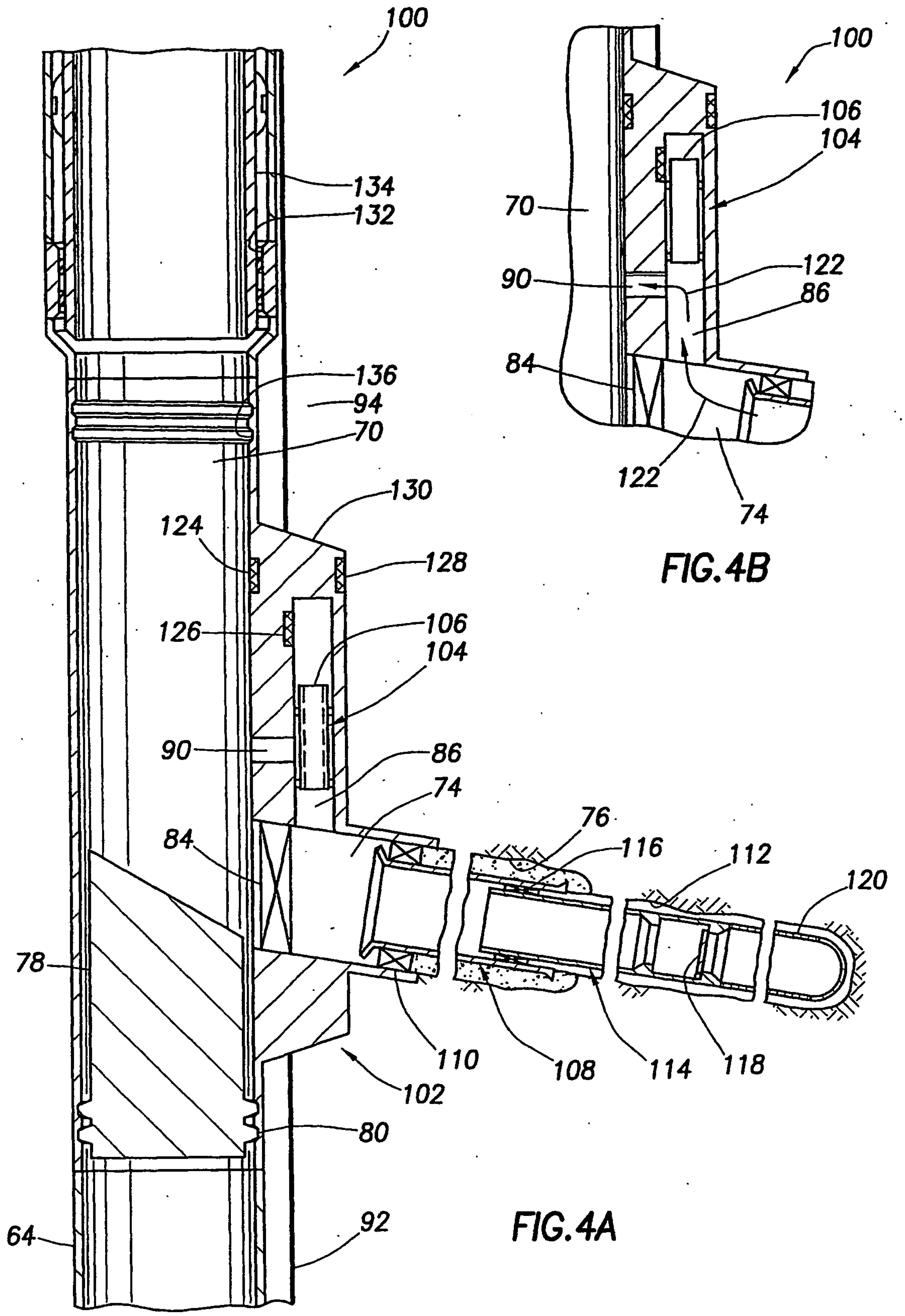


FIG.2
(PRIOR ART)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124
128
126
106
104
90
86
74
76
116
112
120
84
78
110
108
114
118
102
80
64
92
100
106
104
70
90
122
86
84
122
74

FIG.4B

FIG.4A

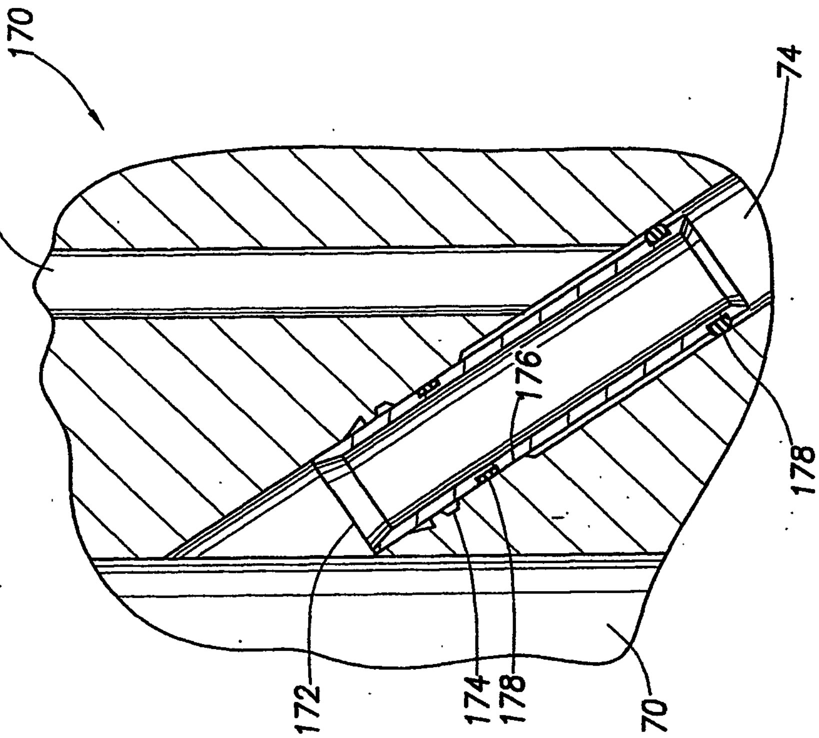
170
86
74
176
178
172
174
178
70

FIG.8

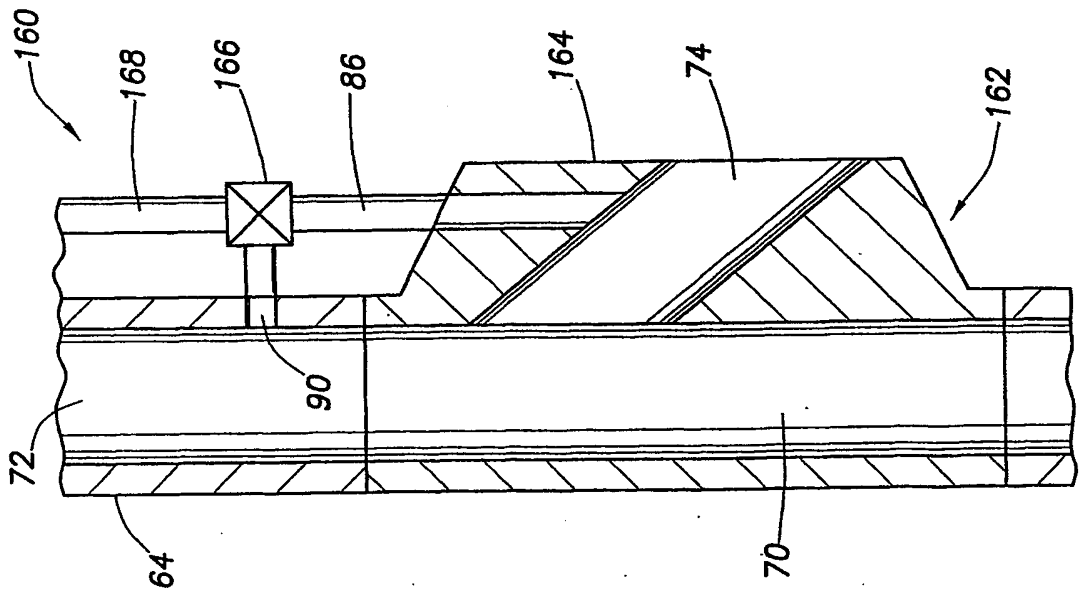
160
168
166
86
164
74
162
90
72
64
70

FIG.7

INTERNATIONAL SEARCH REPORT

International ation No
PCT/US 03/26360

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